abundant food the cells produce heat in increasing measure. Thus, after giving meat alone in large quantity to a quietly resting dog the heat production may be double that of the normal basal metabolism. The constituent amino-acids of protein are relieved of their NH_2 groups and the denitrogenized remainders are utilized for heat production, any excess being converted into glucose and retained in the organism as glycogen. The great rise in heat production is in large measure due to the direct chemical stimulation of the cells through the metabolism products of certain amino-acids. The proof of this lies in the fact that if glycocoll or alanine be given to the diabetic dog the heat production is largely increased, although these substances are not oxidized and there is therefore no evolution of heat from them, for they are converted into glucose and urea which appear in the urine. When the same method is applied to the study of the sugars, it fails to support the idea that the intermediary products of sugar metabolism directly stimulate the cells to a higher heat production. Thus, fructose administered to a diabetic dog caused no increase in heat production, although it underwent chemical change, for it was found as glucose in the urine. Since all the evidence regarding this reaction points to a preliminary cleavage of fructose which contains six carbon atoms into two molecules each containing three atoms of carbon and to the subsequent synthesis of these molecules into glucose, one may reason that the preliminary cleavage products of carbohydrate metabolism are not direct stimuli to protoplasm, as are those of amino-acids like glycocoll and alanine, but that normally the mere presence of a large number of metabolites of sugar results in their oxidation in increased measure.

Rubner has shown that when the yeast cell is bathed in a solution of sugar and peptone the protein is used for growth or cell repair only, while alcoholic fermentation furnishes the energy, and as before stated the quantity of this energy is independent of the strength of the solution. So also in a mammal such as the dog, if one give 50, 70 or 100 grams of glucose, the energy production increases in all cases to a level of about 30 per cent. above the normal. It appears that the cells by a process called "self-regulation" use the fragments of broken glucose up to a certain limit which is not transcended. Any excess of these fragments is converted into glycogen or into fat, a small quantity of energy being absorbed in the first process and a small quantity being liberated in the second. The result of this is that beyond a certain limit of carbohydrate plethora, the heat production in the dog scarcely rises, and this is analogous to the behavior of the yeast cell towards its nutritive environment.

The study of the intermediary metabolism upon which the total heat production of an animal is based, furnishes a fascinating field for the scientist, and it is also evident that the study of the fuel requirement of the human individual in health and in disease presents many problems of importance for the general welfare of the community at large.

GRAHAM LUSK

OBSTACLES TO RESEARCH[1]

THE duty of the university to investigate the unknown as well as to teach the known is clearly evident. In the performance of this duty, the importance of research work is emphasized in many ways. Promise of productive scholarship is a leading qualification demanded in selecting members of the faculty. Encouragement and facilities for original

[1] An address delivered before the Minnesota Chapter of the Sigma Xi Society, October 21, 1915.

work are freely provided. And yet we must confess that the outcome, broadly speaking, is somewhat disappointing, both here and in other universities. It is true that the results in some departments and in many individual cases are satisfactory. On the whole, nevertheless, considering our great opportunities, we seem to add relatively little to the sum total of human knowledge. Why? A recognition of the obstacles to research might enable us in some measure to overcome them. At any rate, the problem is worthy of our earnest and careful consideration.

Let us consider the problem from the biological point of view. The accomplishment of every human being (as of all living things) is the resultant of two factors: heredity and environment. In research work, as in all other lines of activity, the *limits* of possible achievement for each individual depend upon his innate talent, established through heredity. Within these limits, however, the *realization* of possibilities is conditioned by the environment. We must therefore distinguish clearly between (possible) capability or capacity and (actual) accomplishment in the field of original investigation.

The first and most important obstacle in research work is accordingly the limitation of capacity, which is determined by heredity. Since it is now too late to quarrel with our ancestors concerning the matter, as individuals we may as well recognize this as an insurmountable obstacle. From the broad university point of view, this fundamental obstacle may be partially removed by great care in the selection of faculty members. Geniuses are scarce, however, and competition for them very strong; so it is inevitable that even in the strongest universities the faculties must be made up of men with varying degrees of innate talent.

But while our heredity is beyond our control, our environment is not. At least we can modify the environment to a considerable extent. And this is a fact of tremendous practical importance. After all, environment does play an important part in determining both the quantity and the quality of our performance in all lines, including research work. If the environment is sufficiently unfavorable, even the highest genius is sterile. Of two men with equal native ability, one with better opportunity may be far more richly productive than the other. It is a case of seed and soil. The result is determined by heredity plus environment; or perhaps better, heredity *times* environment.

Geniuses are sometimes able to accomplish a great deal, even in a relatively unfavorable environment; but fortunately research work is not a province reserved exclusively for genius. It is encouraging to most of us to remember that the army of investigation requires private soldiers, as well as officers of various grades. Even moderate capacity does not preclude research work of real value. As expressed by John Hunter:

> A man with a sufficient fund of knowledge, and a close application to one art or science, will make great improvements in it though his talents may not be the best; or, in other words, though he be not a great genius.

Conquering the unknown in the field of knowledge is somewhat like civilization invading a new territory. A few bold and talented explorers may lead the way and blaze out new paths in the wilderness; but their excursions would be fruitless unless followed up by pioneer settlers, who by arduous labor develop the country and render its resources available for mankind. Moreover, even the explorer is in many ways largely dependent upon the knowledge and equipment furnished by others, his predecessors and his supporters.

Likewise, in the exploration of the field of knowledge, there is work for all. The history of science abundantly proves that brilliant discoveries and important generalizations usually rest upon a long series of accurate observations, requiring care and patience, but not great genius. A classical example is that of Kepler's laws of planetary motion, founded upon the extensive astronomical observations by Tycho Brahe. In biology, to substantiate and support the cell-doctrine of Schleiden and Schwann, and the doctrine of organic evolution of Darwin, has required an immense

amount of patient labor by a multitude of observers during the past century. Other examples could easily be cited in various fields. The plodders as well as the geniuses should receive their due share of credit for the progress of science.

The production of research work of merit is thus within the capabilities of every one worthy of membership in a university faculty. Doubtless some who are talented predominantly as teachers should devote themselves chiefly to this field, and others are especially fitted for administrative work; but it is desirable that every one should participate to at least a slight extent in research work. As a matter of fact, we may go still further in urging that the *spirit* of scientific research should pervade *all* education, from the kindergarten to the university. Mankind in general is still far from appreciating the fact that the method of science is not a mysterious gift of genius, but a practical tool in the discovery of facts and in their application to the problems of everyday life. As Professor Remsen so aptly expressed it in his address at the dedication of the chemistry building of the University of Minnesota last year, the scientific method is essentially this: "First study the facts; then draw your conclusions from them."

From this point of view, all our problems thus become research problems; and education is able to teach us how to solve them efficiently in proportion to the extent to which training is provided in the methods of original investigation. Thus all education should provide training in scientific research, differing in degree rather than in principle as we pass from elementary to higher education. President Hill (in a recent commencement address at the University of Minnesota) has well said that "The teacher should arouse the spirit of discovery as the first step in the process of learning." A more general recognition of the significance of scientific research for education, a correction of the prevalent error that research is a matter concerning only a chosen few, would remove an obstacle which prevents a more generous support of higher scientific investigation.

While all instruction should be permeated with the research spirit, a conscious effort should be made, especially in the university, to single out as early as possible those students showing unusual talent for original work, and to give them particular aid and encouragement. We must constantly emphasize the necessity for recognition of unusual talent, since otherwise our entire time and energy will tend to be exhausted in caring for the larger number representing mediocrity. This subject is well discussed in a recent report of the subcommittee on the selection and training of students for research (Committee of One Hundred of the American Association for the Advancement of Science), published in SCIENCE, September 17, 1915.

It is, however, not my present purpose to consider the message of science for education in general, but rather to discuss the specific obstacles met by university workers in the field of original investigation. Since we can not change our heredity, possibilities for improvement must be found in the environment. What factors in our environment affect our scientific productivity?

We might classify the environmental factors affecting our research work in two groups: mental and physical. In the first rank, I would place the factors determining our mental attitude toward research. I suspect that investigation lags more frequently from lack of sustained interest than from any other cause. It is doubtless true that one is usually most interested in what one can do especially well. And research ability, as we have already noted, is largely a hereditary matter. Nevertheless, our mental attitude is unquestionably influenced in large measure by the opinion of our colleagues. Appreciation by one's fellows is a most powerful stimulus. Thus a general recognition of good research work will greatly encourage the worker to persist in spite of all obstacles. If Sigma Xi can succeed in establishing a more enthusiastic *esprit de corps* among investigators, it will greatly help the cause of scientific research.

The physical factors affecting research work are also of importance. The obstacles under

this group include lack of material facilities, lack of time and lack of organization. Each of these may be briefly considered in turn.

The material facilities necessary for research include laboratories and equipment of various kinds, supplies, instruments, technical assistants, books, etc. It is customary to cite lack of adequate facilities of this kind to explain shortcomings in scientific productivity. And there is no doubt that more generous provision for these things would greatly facilitate many lines of research work. But, generally speaking, I believe that this factor is somewhat overrated. The man who does nothing because facilities are inadequate would usually accomplish but little even with unlimited resources. On the other hand, the man whose heart is in his research work will rarely fail to secure adequate support, if he perseveres and demonstrates his interest and capability.

Inadequate support of research work is sometimes ascribed to lack of appreciation on the part of university administrative officers, who control the purse-strings. This is usually an unjust accusation. University officers as a rule are keenly anxious to encourage and support research work, but they in turn are always more or less hampered by financial limitations. With the present evidently increasing popular interest in and appreciation of scientific work, however, we may confidently expect in the future more generous provision of funds available for this purpose. Even the "man in the street" can see how Germany has increased her efficiency by systematic encouragement of scientific research. America is likewise beginning to realize that this is not a luxury but a necessity, for which generous support must be provided.

Even more than lack of facilities, lack of time is an obstacle very frequently encountered by university research workers. Many university men are carrying a burden of routine teaching which, if well done, must greatly encroach upon the time absolutely essential for serious research work. In many cases, a considerable amount of routine administrative duties, committee work, etc., is added. Under these conditions, which shall be neglected—teaching, administrative work, or research? Or should one risk the danger of overwork by trying to keep up with all? Surely this is a question hard to answer. The proper solution is of course to provide a sufficient staff to handle the routine teaching and administration, and at the same time leave adequate time free for research. In a rapidly growing university, however, it is difficult to make this provision. But conditions are improving in this respect, and comparatively few men are so overburdened with routine work as to preclude a reasonable amount of time for research.

Lack of time for research work is often due not so much to the actual amount of other work as to waste of time. By carefully planning our university work, much time could be saved. There is too much "scatterment." All too frequently we allow minor routine duties to break in at all times. These minor details should be concentrated so far as possible at certain designated periods, so as to leave uninterrupted consecutive time free for research. A set of office-hours established and rigidly kept will gain a surprisingly large amount of time otherwise frittered away. Thus one serious obstacle to research may be readily removed.

Finally, I believe that another obstacle of importance in many cases is the lack of a proper organization of the research work itself. For the best results, careful, systematic planning is necessary. Too often investigation is taken up in a haphazard sort of way, which is likely to result in failure. While no rule can be made which will apply to all cases, it is certainly true that the topic to be investigated should be carefully considered before the work is undertaken. The literature should be scanned sufficiently to make sure that the contemplated problem has not already been solved, and to render available the experience of others in similar fields. Work should not be undertaken until the necessary facilities are assured to carry it through. In general, a broad fundamental problem of which successive phases may be worked out through a series of years will prove more profitable than a num-

ber of shorter, unrelated subjects of investigation. Wherever possible, cooperation with one's students or colleagues in research will usually yield better results, from the standpoint of economy in time and cost, than will individual efforts. Such matters may seem self-evident to some and trivial to others; but I feel sure that in many cases more attention to them would be well worth while. In short, system is as necessary for efficiency in research as in any other kind of work.

In conclusion, the main points may be emphasized as follows: Obstacles to achievement in research are due partly to inherent or hereditary limits of capacity, and partly to environmental factors. The latter, which are to some extent within our control, include factors determining the mental attitude, which is of primary importance. The remaining factors include the material facilities, increased support for which depends chiefly upon better appreciation by the public of the value of scientific work. Lack of time is often another important obstacle, which in part may be overcome by a more economic arrangement of routine duties. Finally an obstacle in many cases is the lack in the research work itself of systematic planning and organization, which is necessary for the highest efficiency.

C. M. JACKSON

INSTITUTE OF ANATOMY,
UNIVERSITY OF MINNESOTA,
MINNEAPOLIS

DR. CHARLES FREDERICK HOLDER

THE love of nature is so deeply planted in our hearts that even those who have passed most of their lives in the artificial atmosphere of cities respond quickly and warmly to the appeal made by scenic beauty and by the variety and charm of plant and animal life. Hence he who can successfully voice these sentiments and satisfy the desire for a better knowledge of the life, habits and instincts of the denizens of wood, vale and stream, is sure of wide recognition and appreciation.

It can safely be said that no one in our land has more perfectly realized these conditions than the late Dr. Charles Frederick Holder, who passed away on October 10, 1915, in his home at Pasadena, California. At once an enthusiastic sportsman and an enemy to all indiscriminate destruction of animal life, he possessed a rare blend of qualities sometimes regarded as incompatible one with the other. Something of his repugnance to the reckless slaughtering of animals characteristic of too many hunters, may possibly have been due to the fact that he came of stanch Quaker stock, one of his direct ancestors, Christopher Holder, having founded, in 1656, the first society of Friends in America.[1]

Charles Frederick Holder was born in Lynn, Massachusetts, August 5, 1851, and received his early education in the Friends' school at Providence, Rhode Island, and in Allen's preparatory school at West Newton, Massachusetts, as well as from private tutors; later on he developed an inclination toward naval life, and in 1869 entered the United States Naval Academy at Annapolis, but did not pursue the course there up to graduation. From his boyhood he showed the taste for hunting and fishing, and at the same time for the study of the habits of birds and fish, that was destined to grow with his growth and become the aim and pleasure of his life.

In 1871, though but twenty years old, he became assistant curator of the American Museum of Natural History in New York City, and held this position until 1875. The present writer cooperated with Dr. Holder for nine weeks in packing up the 1,000,000 specimens of the James Hall paleontological collection in Albany, prior to their transfer to the American Museum of Natural History in New York City. His marriage to Miss Sarah Elizabeth Ufford, of Brooklyn, took place November 8, 1879.

That one so devoted to nature study and to sport should be attracted toward California, especially toward southern California, can be easily understood; however, ill health was the determining cause of Dr. Holder's removal in 1885 to that state, where he established his

[1] This is related in Dr. Holder's interesting book, "The Holders of Holderness, or Pioneer Quakers."